SLOVENSKI STANDARD

SIST EN 62226-2-1:2005

junij 2005

Izpostavljenost električnim in magnetnim poljem v nizkem in srednjem frekvenčnem obsegu – Metode za izračunavanje trenutne gostote in notranjega induciranega električnega polja v človeškem telesu – 2-1. del: Izpostavljenost magnetnim poljem – 2D model

Exposure to electric or magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body – Part 2-1: Exposure to magnetic fields – 2D models

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English version

Exposure to electric or magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body Part 2-1: Exposure to magnetic fields – 2D models

(IEC 62226-2-1:2004)

Exposition aux champs électriques
ou magnétiques à basse
et moyenne fréquence –
Méthodes de calcul des densités
de courant induit et des champs
électriques induits dans le corps humain
Partie 2-1: Exposition à des champs
magnétiques –
Modèles 2D
(CEI 62226-2-1:2004)

Sicherheit in elektrischen oder
magnetischen Feldern im niedrigen und
mittleren Frequenzbereich –
Verfahren zur Berechnung der induzierten
Körperstromdichte und des im
menschlichen Körper induzierten
elektrischen Feldes
Teil 2-1: Exposition gegenüber
magnetischen Feldern –
2D-Modelle
(IEC 62226-2-1:2004)

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Ref. No. EN 62226-2-1:2005 E

Foreword

The text of document 106/79/FDIS, future edition 1 of IEC 62226-2-1, prepared by IEC TC 106, Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62226-2-1 on 2004-12-01.

This Part 2-1 is to be used in conjunction with EN 62226-1[1)].

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2005-09-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2007-12-01

Endorsement notice

The text of the International Standard IEC 62226-2-1:2004 was approved by CENELEC as a European Standard without any modification.

1) To be published.

NORME INTERNATIONALE

INTERNATIONAL STANDARD

CEI IEC 62226-2-1

Première édition
First edition
2004-11

Exposition aux champs électriques ou magnétiques à basse et moyenne fréquence – Méthodes de calcul des densités de courant induit et des champs électriques induits dans le corps humain –

Partie 2-1: Exposition à des champs magnétiques – Modèles 2D

Exposure to electric or magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body –

Part 2-1: Exposure to magnetic fields – 2D models

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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EXPOSURE TO ELECTRIC OR MAGNETIC FIELDS IN THE LOW AND INTERMEDIATE FREQUENCY RANGE – METHODS FOR CALCULATING THE CURRENT DENSITY AND INTERNAL ELECTRIC FIELD INDUCED IN THE HUMAN BODY –

Part 2-1: Exposure to magnetic fields – 2D models

FOREWORD

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International Standard IEC 62226-2-1 has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure.

This Part 2-1 is intended to be used in conjunction with the first edition of IEC 62226-1:2004, *Exposure to electric or magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body – Part 1: General.*

The text of this standard is based on the following documents:

FDIS	Report on voting
106/79/FDIS	106/83/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

This International Standard constitutes Part 2-1 of IEC 62226 series, which will regroup several international standards and technical reports within the framework of the calculation of induced current densities and internal electric fields, and will be published under the general title of *Exposure to electric or magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body.*

This series is planned to be published according to the following structure:

Part 1: General

Part 2: Exposure to magnetic fields

Part 2-1 : 2D models

Part 2-2 : 3D models

Part 2-3 : Guidelines for practical use of coupling factors

Part 3: Exposure to electric fields

Part 3-1: Analytical and 2D numerical models

Part 3-2: 3D numerical models

Part 4: Electrical parameters of human living tissues (Technical Report)

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

INTRODUCTION

Public interest concerning human exposure to electric and magnetic fields has led international and national organisations to propose limits based on recognised adverse effects.

This standard applies to the frequency range for which the exposure limits are based on the induction of voltages or currents in the human body, when exposed to electric and magnetic fields. This frequency range covers the low and intermediate frequencies, up to 100 kHz. Some methods described in this standard can be used at higher frequencies under specific conditions.

The exposure limits based on biological and medical experimentation about these fundamental induction phenomena are usually called “basic restrictions”. They include safety factors.

The induced electrical quantities are not directly measurable, so simplified derived limits are also proposed. These limits, called “reference levels”, are given in terms of external electric and magnetic fields. They are based on very simple models of coupling between external fields and the body. These derived limits are conservative.

Sophisticated models for calculating induced currents in the body have been used and are the subject of a number of scientific publications. These use numerical 3D electromagnetic field computation codes and detailed models of the internal structure with specific electrical characteristics of each tissue within the body. However such models are still developing; the electrical conductivity data available at present has considerable shortcomings; and the spatial resolution of models is still advancing. Such models are therefore still considered to be in the field of scientific research and at present it is not considered that the results obtained from such models should be fixed indefinitely within standards. However it is recognised that such models can and do make a useful contribution to the standardisation process, specially for product standards where particular cases of exposure are considered. When results from such models are used in standards, the results should be reviewed from time to time to ensure they continue to reflect the current status of the science.

EXPOSURE TO ELECTRIC OR MAGNETIC FIELDS IN THE LOW AND INTERMEDIATE FREQUENCY RANGE – METHODS FOR CALCULATING THE CURRENT DENSITY AND INTERNAL ELECTRIC FIELD INDUCED IN THE HUMAN BODY –

Part 2-1: Exposure to magnetic fields – 2D models

1 Scope

This part of IEC 62226 introduces the coupling factor K, to enable exposure assessment for complex exposure situations, such as non-uniform magnetic field or perturbed electric field. The coupling factor K has different physical interpretations depending on whether it relates to electric or magnetic field exposure.

The aim of this part is to define in more detail this coupling factor K, for the case of simple models of the human body, exposed to non-uniform magnetic fields. It is thus called "coupling factor for non-uniform magnetic field".

All the calculations developed in this document use the low frequency approximation in which displacement currents are neglected. This approximation has been validated in the low frequency range in the human body where parameter $\varepsilon\omega \ll \sigma$.

For frequencies up to a few kHz, the ratio of conductivity and permittivity should be calculated to validate this hypothesis.

2 Analytical models

2.1 General

Basic restrictions in guidelines on human exposure to magnetic fields up to about 100 kHz are generally expressed in terms of induced current density or internal electric field. These electrical quantities cannot be measured directly and the purpose of this document is to give methods and tools on how to assess these quantities from the external magnetic field.

The induced current density J and the internal electric field E_i are closely linked by the simple relation:

$$J = \sigma E_i \tag{1}$$

where σ is the conductivity of living tissues.

For simplicity, the content of this standard is presented in terms of induced current densities J, from which values of the internal electric field can be easily derived using the previous formula.

Analytical models have been used in EMF health guidelines to quantify the relationship between induced currents or internal electric field and the external fields. These involve assumptions of highly simplified body geometry, with homogeneous conductivity and uniform applied magnetic field. Such models have serious limitations. The human body is a much more complicated non-homogeneous structure, and the applied field is generally non-uniform because it arises from currents flowing through complex sets of conductors and coils.

For example, in an induction heating system, the magnetic field is in fact the superposition of an excitation field (created by the coils), and a reaction field (created by the induced currents in the piece). In the body, this reaction field is negligible and can be ignored.

Annex E and F presents the analytical calculation of magnetic field H created by simple sources and Annex G presents the analytical method for calculating the induced current in a conductive disk.

2.2 Basic analytical models for uniform fields

The simplest analytical models used in EMF health guidelines are based on the hypothesis of coupling between a uniform external magnetic field at a single frequency, and a homogeneous disk of given conductivity, used to represent the part of the body under consideration, as illustrated in Figure 1. Such models are used for example in the ICNIRP [1)] and NRPB [2)] guidelines.

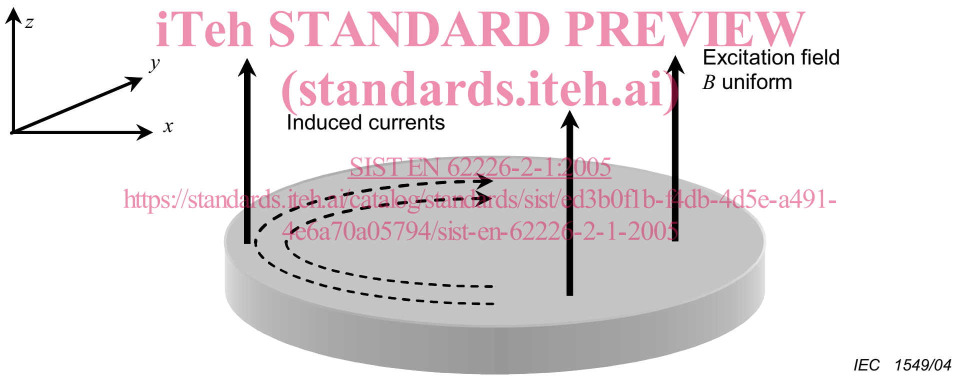

Figure 1 – Conducting disk in a uniform magnetic flux density

The objective of such a modelling is to provide a simple method to assess induced currents and internal fields. This very first approach is simple and gives conservative values of the electrical quantities calculated.

For alternating magnetic fields, the calculation assumes that the body or the part of the body exposed is a circular section of radius r, with conductivity σ. The calculation is made under maximum coupling conditions i.e. with a uniform magnetic field perpendicular to this disk. In this case, the induced current density at radius r is given by:

$$J(r) = \frac{r\sigma}{2}\frac{dB}{dt} \qquad (2)$$

where B is the magnetic flux density.

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1) Health Physics (vol. 74, n° 4, April 1998, pp 496-522).

2) NRPB, 1993, Board Statement on Restrictions on Human Exposure to Static and Time-varying Electromagnetic Fields and Radiation, Volume 4, No 5, 1.

For a single frequency f, this becomes:

$$J(r) = \sigma \pi r f B \quad (3)$$

As illustrated in Figure 1 (see also Annex A), induced currents are distributed inside the disk, following a rotation symmetry around the central axis of the disk. The value of induced currents is minimum (zero) at the centre and maximum at the edge of the disk.

3 Numerical models

3.1 General information about numerical models

Simple models, which take into consideration field characteristics, are more realistic than those, which consider only uniform fields, such as analytical ones.

Electromagnetic fields are governed by Maxwell's equations. These equations can be accurately solved in 2- or 3-dimensional structures (2D or 3D computations) using various numerical methods, such as:

- finite elements method (FEM);
- boundary integral equations method (BIE or BEM), or moment method;
- finite differences method (FD);
- impedance method (IM).

Others methods derive from these. For example, the following derive from the finite differences method:

- finite difference time domain (FDTD);
- frequency dependent finite difference time domain ($(FD)^2TD$);
- scalar potential finite difference (SPFD).

Hybrid methods have been also developed in order to improve modelling (example: FE + BIE).

Commercially available software can accurately solve Maxwell's equations by taking into account real geometrical structures and physical characteristics of materials, as well as in steady state or transient current source conditions.

The choice of the numerical method is guided by a compromise between accuracy, computational efficiency, memory requirements, and depends on many parameters, such as:

- simulated field exposure;
- size and shape of human object to be modelled;
- description level of the human object (size of voxel), or fineness of the meshing;
- frequency range, in order to neglect some parts of Maxwell's relations (example: displacement current term for low frequency);
- electrical supply signal (sinusoidal, periodic or transient);

– type of resolution (2D or 3D);
– mathematical formulation;
– linear or non linear physical parameters (conductivity, …);
– performances of the numerical method;
– etc.

Computation times can therefore vary significantly.

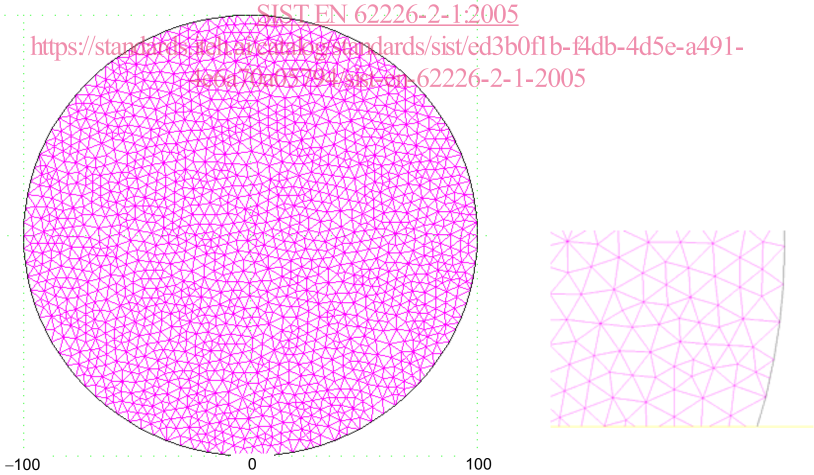
Computed electromagnetic values can be presented in different ways, including:

– distributions of magnetic field H, flux density B, electric field E, current density J. These distributions can be presented in the form of coloured iso-value lines and/or curves, allowing a visual assessment of the phenomena and the possible "hot" points;
– local or spatial averaged integral values of H, B, E, J, etc.;
– global magnitude values: active power.

These methods are very helpful for solving specific problems; however they cannot be conveniently used to study general problems.

3.2 2D models – General approach

In order to gain quickly an understanding of induced currents in the human body, 2D simulations can be performed using a simple representation of the body (a conductive disk: example of modelling given in Figure 2) in a non-uniform magnetic field, as illustrated in Figure 3.



IEC 1550/04

Figure 2 – Finite elements meshing (2nd order triangles) of a disk, and detail